

## REMARKS

In the Official Action, Claims 30, 43 and 55-57 stand rejected under 35 U.S.C. §112, second paragraph, as allegedly failing to particularly point out and distinctly claim the subject matter which applicants regard as the invention. Specifically, with respect to Claim 30, the Official Action avers that the claimed process is in a passive voice alleging that it is not clear as to what specific process steps are intended.

In response, applicants have rewritten Claim 30 as shown above. Support for this amendment can be found in the originally filed Claim 30.

As far as Claims 55-57 are concerned, the Official Action alleges that the term “difference in SFC...more than” recited therein is a relative term which renders the claims indefinite. Moreover, the Official Action avers that there is no definition of the term “SFC”.

In response, applicants have rewritten Claim 55-57, defining the abbreviation in a manner as shown above. Support for this amendment can be found in the originally filed Claims 30 and 55-57 and on page 1, line 22 of the originally filed specification. Further, Claim 55 has been amended to recite that the fat is a non-temper fat. Support is found on Page 72, lines 6-8 of the instant specification and in original Claim 58, which has been cancelled.

Regarding Claim 43, the Official Action alleges that it recites a broad range and a narrow range.

In response, applicants have amended Claim 43 and added a new Claim 86 in a manner as shown above. Support for Claim 86 amendment can be found in the originally filed Claim 43.

Since the amendments do not introduce any new matter into the application, entry thereof is respectfully requested. Since the amendments to Claim 30, 43 and 55-57 obviates the

35 U.S.C. §112, second paragraph rejection, reconsideration and withdrawal of the instant rejection is respectfully requested.

The Official Action further alleges that Claims 30-44, 46-57 and 59-85 stand rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over U.S. Patent No. 3,686,240 to Kawada et al. ("Kawada") as further evidenced by the specification at page 10, lines 3-21 and "Fractionation of Palm Oil" by Deffense et al. ("Deffense"), JAOCS, Vol 62, No.2, page 376-385, 1985.

Specifically, the Official Action alleges that Kawada teaches that palm middle melting fraction is hydrogenated to a trans acid content of 1% (see column 5, lines 36-40). The Official Action further avers that the glyceride claimed in the present application is palm middle melting fraction (see page 10, lines 3-21 of the specification). Therefore, the Official Action asserts that Claim 30 of the present application differs from Kawada as further evidenced by Deffense in the recitation of the extent of C18-0 in the hydrogenated product. Furthermore, the Official Action alleges that since the starting materials and the resulting trans acids content of the hydrogenation process are the same between Kawada and the present application, it concludes that a person skilled in the art would expect the extent of C18-0 to also be the same as a result of the process disclosed by Kawada.

In response, applicants respectfully submit that this is not the case. Specifically, applicants submit that Claim 30 and all its dependent claims of the present application are directed to a process where the resulting product is a non-tempering fat composition (see Claim 30). In contrast, Kawada discloses a process for preparing a cocoa butter substitute from palm oil where the resulting product is a tempering fat composition. See column 1, lines 15-25.

The above observation is evidenced by comparing the teachings of Kawada with the teachings of the attached enclosure ("Exhibit A"), which is an excerpt from a general handbook on oil and fat products entitled "Bailey's Industrial Oil and Fat Products" vol. 3, 5<sup>th</sup> Ed, Wiley-Interscience Publication, NY, NY, year, p. 368-391 ("Bailey's"). Attention is directed to page 381, where it is stated "...equivalents are fats that behave like and are compatible with cacao butter in any proportion. They do not alter the melting, processing and rheological properties of cocoa butter...". Specifically, Bailey's discloses that the stable crystal form is the beta-type (SUS) which means that the fat needs tempering. See Bailey's, table 9.11, p 381 and last paragraph on 383, which refers to CBE and their beta polymorphs.

As described in Kawada, the product of Kawada exhibits properties similar to cocoa butter which is a tempering fat (see Col. 1, lines 33-34 of Kawada). Furthermore, according to Kawada, the melting point of the fat produced by the process is not lowered and does not soften upon blending with natural cocoa butter (see Col. 1, lines 71-72 of Kawada). This characteristic is consistent with the product in Kawada being a tempering fat. In fact, as indicated in Bailey's on Page 331, a tempering fat is compatible with cocoa butter in any proportion. On the other hand, a non-tempering fat would not exhibit such characteristics. Additionally, the procedure disclosed in Kawada for measuring the Solid Fat Index (SFI) involves a tempering step. According to Kawada, the fat composition produced is subjected to an aging process at 30°C for 3 days (See, Col. 4, line 58 of Kawada) and at 25°C for 3 days, respectively (Col. 4, line 53). However, non-tempering fat compositions are not subjected to such a temperature time-program when measuring the SFI.

Therefore, in view of the above remarks, applicants submit that it is clear that the fat produced in Kawada is a tempering fat. On the other hand, the fat composition in the present

invention is a non-tempering fat. Since a non-tempering fat and tempering fat have different characteristics, the compositions of the tempering fat would have to be different from the non-tempering fat of the invention. Thus, it follows that a process described in Kawada to make a tempering fat could not be used to make a composition containing a non-tempering fat.

To further support that the fat composition of the present invention is different from that described in Kawada, applicants have conducted experiments, as described set forth below, to compare the fat composition of the present invention with that described in Kawada.

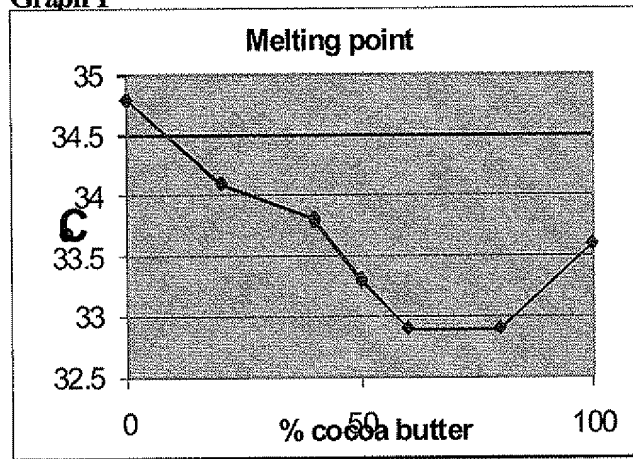
Specifically, a representative fat composition prepared by the presently claimed process was obtained by the following process. A starting fat composition was utilized, having a glyceride composition as S2U: 75.74 wt. %; SU2 + U3: 17.03 wt. %; S3: 1.52 wt. %; and Diglyceride-content: 3.34 wt. %. It was subjected to a hydrogenation reaction using a non trans specific catalyst Pricat 9910 according to the procedures as described in the above-identified application. The obtained product was a non-tempering fat ("Fat NR-1") with the following characteristics (Solid Fat Content (SFC) according to IUPAC 2.150-a): Trans Fatty Acids (TFA) content: 4.09 wt. %; SFC at 20°C: 67.5 %; SFC at 35°C: 3.4 %. Fat NR-1 was then subjected to a number of tests in combination with cocoa butter (CB).

The following assay was used to measure the melting point of the product prepared in the above. The melting point of Fat NR-1 was determined as the pure fat and in different blends with cocoa butter, according to the method described in Kawada, i.e., by first cooling to 5°C and keeping it overnight, then aging for 3 days at 30°C, followed by measuring the melting point at the blend. The results are shown in the following Table 1 and in Graph 1.

**Table 1**

| Fat NR-1 | CB  | MP-Tempered 3 d |
|----------|-----|-----------------|
| 100      | 0   | 34.8            |
| 80       | 20  | 34.1            |
| 60       | 40  | 33.8            |
| 50       | 50  | 33.3            |
| 40       | 60  | 32.9            |
| 20       | 80  | 32.9            |
| 0        | 100 | 33.6            |

**Graph 1**



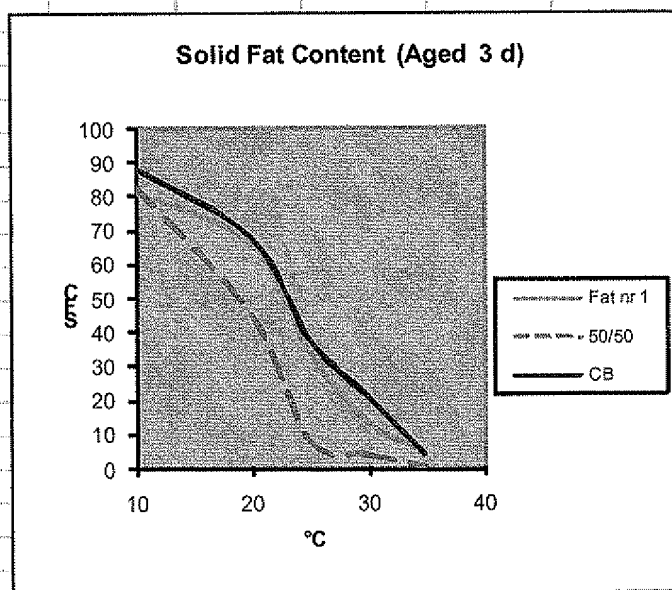
As clearly shown from Graph 1, in certain blending proportions, the melting point of the blend is lower than the melting point of cocoa butter (which is 34-35 °C for the beta-type, See Table 9.9 at page 371 of Bailey's). This means that the fat composition Fat NR-1 of the present application does not fulfill the requirements of Kawada. If the product were fat prepared in accordance with the teachings of Kawada, Kawada explains in col. 1, lines 71-72 that the melting point should not be lowered and the blend would not soften upon blending with natural cocoa butter. Therefore, since the fat obtained according to the presently claimed process does not have this characteristic, it is clear that such fat composition is a non-tempering type of fat, whereas the fat composition disclosed in Kawada is a tempering type of fat.

Moreover, another test measured the solid fat content of Fat NR-1. The solid fat content was measured with NMR, applying the same cooling and aging procedure as described in Kawada, i.e. first solidifying in ice water, then aging for 3 days at 30 °C, followed by measuring the solid fat content of the Fat NR-1 and of a 50/50 mixture of the Fat NR-1 with cocoa butter (the same combinations as described in example 1 of Kawada). The results are summarized in Table 2 and Graph 2.

**Table 2**

| Fat NR-1 | CB  | SFC-Tempered 3 days |      |      |      |     |
|----------|-----|---------------------|------|------|------|-----|
|          |     | 10                  | 20   | 25   | 30   | 35  |
| 100      | 0   | 81.6                | 66.3 | 34.1 | 13.1 | 5.5 |
| 50       | 50  | 83.1                | 45.4 | 8.2  | 4.1  | 0.7 |
| 0        | 100 | 88.6                | 68   | 37.6 | 20.9 | 4.3 |

**Graph 2**



As clearly demonstrated by Graph 2, Fat NR-1 showed a strong eutectic effect, the solid fat content of the 50/50 combination is much lower than the two components individually. A 50/50 mixture of cocoa butter and a tempering fat would not exhibit this eutectic effect for the

reason explained by Bailey's, since a tempering fat is compatible with cocoa butter. This data show that Fat NR-1 is not a tempering fat, as disclosed in Kawada, but rather a non-tempering fat composition.

Furthermore, another test conducted was the chocolate application test. This assay investigated whether Fat NR-1 is suitable for use as a cocoa butter substitute by utilizing the process for making chocolate which includes a tempering step with fat NR-1 and cocoa butter. A coating was prepared (see Table 3) comprising Fat NR-1 and cocoa butter in a ratio of 85.4% / 14.6%. A dark chocolate product (tablet) with 100% cocoa butter was prepared as a reference. The products were prepared as follows: after the fat had been made molten, all ingredients, except part of the fat, were mixed and roll refined. Then the mixed ingredients were further homogenized with the rest of the fat in a mixer with heated jacket at a temperature of 40°C. Samples of this blend were taken and tempered at different conditions. For each sample, the viscosity, and the minimum and reheating temperature applied during tempering were recorded. The tempered products were moulded, cooled for 30 minutes at 5°C and thereafter for 30 minutes at 15°C, following which the products (tablets) were de-moulded. The de-moulding properties (shrinkage) were also checked. Thereafter the products were stored in an incubator at 20°C. The appearance of the products was checked after 3 weeks. The results of these tests are summarized in Table 4.

**Table 3**

| <b><u>Coating Recipe</u></b> | <b>%</b> |
|------------------------------|----------|
| Fat                          | 29.2     |
| Sugar                        | 44.7     |
| Cocoapowder 10/12            | 20.6     |
| Cocoa Mass                   | 5.1      |
| Lecithine                    | 0.4      |
| Vanilline                    | 0.05     |
| Cocoa butter on total fat    | 14.8     |

**Table 4**

| <b>Fat NR 1</b>     |       | visual appearance |           |                  |                       |       |
|---------------------|-------|-------------------|-----------|------------------|-----------------------|-------|
|                     | T min | T reheat          | viscosity | demoulding after | demould after 3 weeks |       |
| test 1              | 26.5  | 30.5              | OK        | very bad         | OK                    | bloom |
| test 2              | 24.3  | 26.5              | OK        | very bad         | OK                    | bloom |
| test 3              | 23.8  | 25.9              | high      | bad              | start bloom           | bloom |
| test 4              | 23.8  | 25.8              | high      | reasonable       | start bloom           | bloom |
| <b>cocoa butter</b> |       |                   |           |                  |                       |       |
|                     | 26.5  | 30.5              | OK        | good             | OK                    | OK    |

As can be seen from Table 4, none of the tempering conditions utilized gave a fat composition which when mixed with cocoa butter gave a stable product. The viscosity was found to be too high to achieve adequate tempering, and all products showed quick fat blooming (white surface), indicating that the fat was not stabilized properly. Therefore, it is clear that Fat NR-1 can not be utilized in Kawada. As such, this experiment confirms that Fat NR-1 is a different type of fat than the fat disclosed in Kawada.

The different characteristics of the fat compositions of the present application and the fat compositions disclosed in Kawada are further established by the following experiment. A representative fat composition according to the above-identified application, identified as Fat NR-2, was prepared starting from a fat with the following glyceride composition: S2U: 69.51%; SU2 + U3: 18.57%; S3: 1.29 %; Diglyceride-content: 8.85 %. The starting fat was hydrogenated with a catalyst Pricat 9910 and gave a fat composition with the following characteristics: TFA-content : 7.71 % ; SFC 20°C : 71.1 % ; SFC 35°C : 11.3 %. Fat NR-2 was then used to make a confectionery coating using the ingredients in the amounts set forth below in Table 5.



**Table 5**

| <b><u>Coating Recipe</u></b> | <b>%</b> |
|------------------------------|----------|
| Fat                          | 34.8     |
| Sugar                        | 49.8     |
| Cocoapowder 10/12            | 15       |
| Lecithine                    | 0.4      |
| Vanilline                    | 0.02     |

The procedure utilized for the preparation of the above coating was the same as described above in the chocolate application test, except that no tempering was applied before moulding. The tablets could be easily de-moulded. The resulting tablets were then stored in an incubator at 20°C to check their stability. After 9 months storage, the tablets still exhibited no fat bloom (no white appearance). Further, no crystals or defects were seen at the surface and the tablets remained very glossy.

To demonstrate the difference with cocoa butter, the following tests were conducted: a molten dark chocolate, containing only cocoa butter and no confectionery fat, was moulded and solidified applying the same cooling procedure as given above, but without any tempering step. The result was that big crystals appeared at the surface of the tablets with cocoa butter in less than one day.

As a comparison, the same experiment described above was repeated using tempered cocoa butter as in Kawada. Its appearance was very similar to the one made with the Fat NR-2, although the latter may be much older. Therefore, the conclusion is that the fat composition obtained from the present application is stable without tempering, and thus is a non-tempering type of fat. On the other hand, the fat composition in Kawada is not stable without tempering.

Consequently, as shown by the experiments hereinabove, the fat composition in Kawada and the fat composition of the present application are quite different. The fat prepared in Kawada is a tempering fat, while that produced in accordance with the present application is a non-

tempering fat. Thus, the fat produced in accordance with the present application has different characteristics and properties relative to the fat described in Kawada. As such, the conclusion is compelling that fat produced by the present process is not taught, disclosed or suggested by Kawada. Moreover, the process of preparing the temper fat composition of the present invention is not taught, described or suggested by the process described in Kawada since it produces a tempering fat and not a non-tempering fat, as claimed.

Regarding the secondary reference, Deffense, applicants submit that the teachings in Deffense are not relevant. Specifically, Deffense is a general publication which discloses the triglyceride composition of palm oil fractions of different origins and fractions. It does not teach, disclose or suggest the presently claimed process where the resulted product is a non-tempering fat or the fat composition prepared by said process, or a product containing said fat composition.

Therefore, neither Kawada nor Deffense alone or in combination teach, disclose or suggest a non-tempering fat composition as claimed or the process of preparing the same or a composition containing same, as claimed. Furthermore, even if the references were combined, the combination would suggest a composition that contains a tempering fat and not a non-tempering fat composition, as claimed. Since tempering fat and non-tempering fat have different characteristics, it follows that the compositions are not only different but that a reference teaching a tempering fat would not teach, disclose or suggest a composition containing non-tempering fat, as claimed. Further, the process resulting from the combination of references directed to preparing a tempering fat would not teach, disclose or suggest the claimed process for preparing a non-tempering fat composition.

In view of the above remarks, applicants submit that the §103 rejection has been obviated, and thus reconsideration and withdrawal of the instant rejection is respectfully requested.

Furthermore, in the Official Action, Claims 45 and 58 stand rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over Kawada as further evidenced by the specification on page 10, lines 3-21 and Deffense, and further in view of U.S. Patent Application Publication No. 2004/0146626 to Higgins et al. ("Higgins"), U.S. Patent No. 4,161,483 to Cahen ("Cahen"), and U.S. Patent No. 6,265,596 to Harrod et al. ("Harrod").

Specifically, with respect to Claim 45 wherein the hydrogenation catalyst is Ni, the Official Action avers that a person skilled in the art, in view of the teachings of Higgins, Cahen and Harrod wherein Ni is used as a hydrogenation catalyst to produce low levels of trans acids, would substitute the copper-chromium-manganese oxide catalyst disclosed in Kawada by Ni to arrive to the present invention.

Regarding Claim 58 wherein the fat composition is recited as a non-temper fat, the Official Action avers that a person skilled in the art would not expect that the hydrogenated fat disclosed in Kawada is a tempering fat. Furthermore, the Official Action alleges that hydrogenating combinations of oils is well known in the art, so a person skilled in the art would expect that some of these fats would be non-tempting fats.

It is to be noted that Claim 55 incorporates the subject matter of Claim 58; thus, the rejection against Claim 58 is moot. Applicants, however, are addressing the rejection as it relates to the subject matter of Claim 55 relating to a non-tempering fat.

Applicants reiterate the comments hereinabove with to Kawada and Deffense, the contents of which are incorporated by reference. As described hereinabove, the fat composition

prepared by the process recited in the claims as well as the product prepared by the process of the present invention is a non-temper fat composition, while the teachings of Kawada and Deffense suggest a temper fat.

The Office Action has cited Higgins, Cahen and Harrod to substitute the catalyst described therein for the catalyst used in Kawada. Applicants respectfully submit that this combination is improper for there is not motivation to make the substitution. The decision is KSR International Co. v. Teleflex Inc., 127 Set. 1727 (2007) acknowledges the importance of identifying a “reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in a way the claimed new invention does”. KSR at 1741. It still remains necessary to identify some reason that would have motivated one of ordinary skill in the art to modify the teachings in a prior art to establish a case of prima facie obviousness. Takeda Chemical Industries Ltd. v. Alphapharma Pty. Ltd., 492 F.3d 1350, 83 USPQ 1169 (Fed. Cir. 2007). Moreover, if the proposed modification would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims prima facie obvious. In re Ratti, 270 F.2d 810, 123 USPQ 349 (CCPA 1959).

Applicants respectfully submit that there is no motivation for one of ordinary skill in the art to combine the references of Kawada and Deffense with Cahen, Higgins and Harrod et al. because the proposed modification by the USPTO may not achieve the objective in Kawada and may change the principle of operation of Kawada.

The objective in Kawada is to make a cocoa butter substitute that should melt near or at body temperature and blend with natural cocoa butter, so that the resulting melting point is not lowered. That is, the objective was to make tempering fat, contrary to the allegations of the Official Action. Thus, to maintain those properties, one does not arbitrarily utilize the teachings

of references which suggest the use of other catalysts, unless these catalysts would maintain the fat as a tempering fat. One skilled in the art understands which catalysts to use to maintain a tempering fat. Although Kawada indicates that it wishes to limit the amount of trans acid content to less than 5%, it does not discuss whether the hydrogenation of unsaturated C<sub>18</sub> fatty acids to C<sub>18</sub> saturated fatty acids is limited. To make non-tempering fats, both the formation of trans fatty acids is limited and the hydrogenation of unsaturated C<sub>18</sub> fatty acids to C<sub>18</sub> saturated fatty acids is limited. Thus, since the goal of Kawada is to produce a tempering fat, one of ordinary skill in the art would not utilize specific catalysts that would not make a tempering fat and therefore would not combine the teachings of Kawada with a reference which when applied could make any other type of fat, and/or create a product which is contrary to the intended purpose of producing a temper fat.

Thus, there would be no motivation to combine the teachings of Kawada and Deffense with Higgins, Cahen and Harrod, unless the resulting product is a tempered fat or the resulting process produces a tempering fat, which teaches away from the process and compositions of the present invention for making a non-tempered fat. Therefore, this rejection under 35 U.S.C. §103 is overcome, withdrawal thereof is respectfully requested.

In view of the foregoing amendments and remarks, it is firmly believed that the subject application is in condition for allowance, which action is earnestly solicited.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Mark J. Cohen". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

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MJC/AZ:dk

## EXHIBIT A

A 1.

# **BAILEY'S INDUSTRIAL OIL AND FAT PRODUCTS**

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*Fifth Edition*

*Volume 3*

*Edible Oil and Fat Products:  
Products and Application Technology*

*Edited by*

**Y. H. HUI**

*Technology and Commerce, International*



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Wiley m.p. corresponds to an SFI of 3; Mettler dropping point m.p. corresponds to an SFI of about 1.5; and the complete m.p. is at an SFI of 0.

Finally, it is emphasized that Table 8.1 gives typical physical specifications for a number of bakery shortenings; adjustments can and should be made to meet requirements for a particular product or equipment line. The values given are meant as guidelines, and a complete ingredient specification should be developed in consultation with shortening suppliers.

## REFERENCES

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# 9

## Oils and Fats in Confections

Fats and oils are found in a variety of confectionery products. Applications and levels of usage cover a broad range. For example, they might be employed as a vehicle for flavoring agents (processing aid) and thus make a negligible contribution to the total fat content. At the opposite end of the spectrum, fat levels exceeding 50% for meltways and truffles and 60% for frozen novelty coatings are common. Fats and oils contribute to flavor, texture, eye appeal, aroma, mouthfeel, and generally significantly dictate the overall quality of the eating experience. They are found in centers, coatings, solid and hollow molded pieces, and also serve as roasting media for frying nutmeats, release agents/lubricants for equipment and wrappers, and vehicles for flavorants, colorants, and polishing agents and glazes. Given the myriad roles satisfied by fats and oils in confectionery products, it is easy to appreciate that this ingredient is often paramount to the quality delivered in the finished confection. Demands placed on the fat and oil might include (1) the ability to deliver a unique characteristic flavor (e.g., cocoa butter, butterfat); (2) conversely, not contribute to the flavor at all but rather provide structure, shortness, or lubricity or perhaps to suspend other ingredients selected for their ability to deliver flavor and aroma in an acceptable form between factory and consumer; (3) provide gloss, surface finish, and eye appeal; (4) serve as a heat transfer medium during roasting processes; (5) provide a moisture barrier; and (6) postpone oil migration. For many confectionery applications, where fat is more than a processing aid, lipids constitute the continuous phase and are present at significant levels.

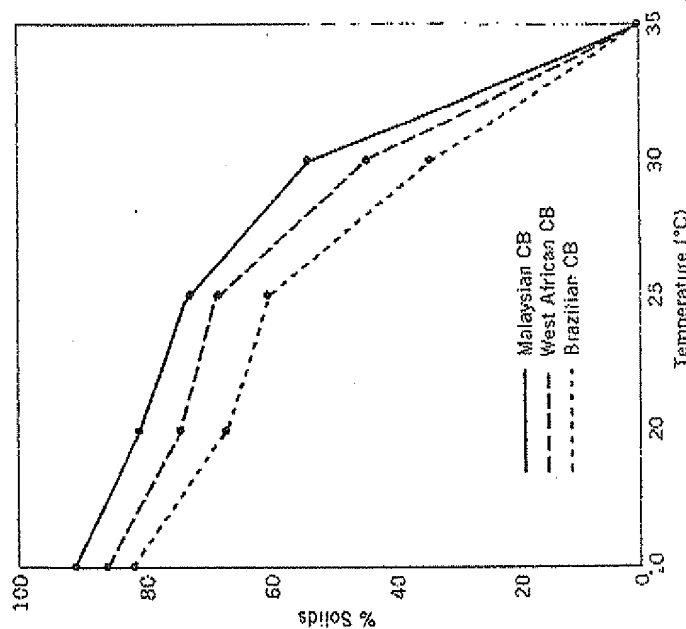


Figure 9.4 Typical melting profile of origin cocoa butters: Malaysian, West African, and Brazilian.

ingredients contained therein become available to contribute to sweetness, chocolaty flavor and aroma, and the other sensory experiences associated with chocolate.

Any solid fat remaining above 35°C is undesirable as it will be recognized as waxy and chewy and will not give up much of the aromas and flavors entrapped within. Generally, more flavor has to be added to fat-rich products in order to deliver the desired impact. Consider, for example, (1) chocolate, (2) chocolate-flavored ice cream, and (3) chocolate-flavored skimmed milk. The fat content for each is approximately 35, 10, and 0.2%, respectively, while cocoa solids represent 16, 2.5, and 1.3%. Fat masks the bitter element (theobromine) of cocoa as well as the sour note, and thus alkalinized powders are not often used in higher-fat-content products. On the other hand, aqueous systems tend to highlight bitter notes, and the typically lower fat contents of such systems lack the masking effect. Consequently, alkalinized powders are usually selected for chocolate-flavored milk, for example (31).

Triglycerides are believed to conform to a chair or tuning fork configuration, regardless of whether in the liquid or solid state. Furthermore, in the crystalline state, triglycerides likely exist as dimers. The longitudinal packing is determined by the degree of unsaturation and chain lengths of the constituent fatty acids. Most saturated triglycerides containing a single acid, for example tristearin (StStSt), pack into a double chain length structure. However, those triglycerides containing fatty acid moieties of varying chain length (more than four carbon atoms difference between longest and shortest fatty acid) tend to exhibit triple chain length packing (Figure 9.5). This is also the case for triglycerides that contain an unsaturated fatty acid at the  $\beta$  position. Hence, the packing arrangement for crystallized cocoa butter closely approximates the triple chain length configuration (32).

Fundamentally, three crystal forms are typically discussed, each exhibiting different stability. The  $\alpha$  form is normally the first to develop upon cooling from the melt and is often only transitory because as its melting point is approached it transforms rapidly into the more stable  $\beta'$  form. This transition may require a matter of seconds to several hours. Under the appropriate conditions, the  $\beta'$  form transforms to the most stable  $\beta$  crystal. This change

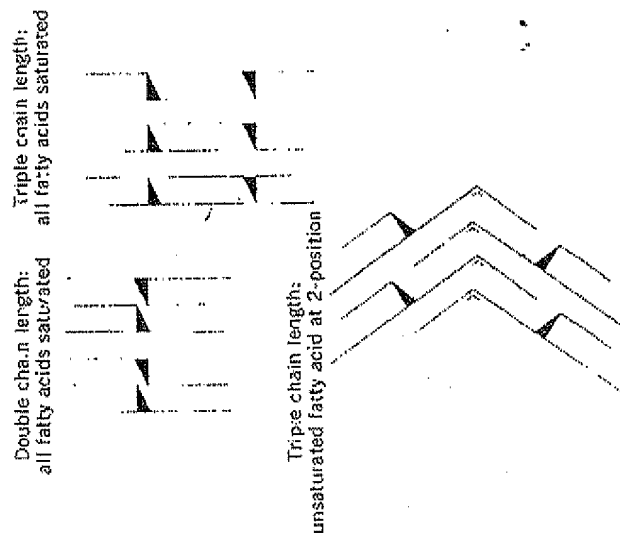


Figure 9.5 Crystalline packing arrangements of triglycerides.

Table 9.9 Properties of cocoa butter polymorphs reported by Vaack (35)

| Polymorph | Melting Point (°C) | Latent Heat of Fusion | Approximate Life | Contraction from Liquid |
|-----------|--------------------|-----------------------|------------------|-------------------------|
| $\alpha$  | 21-24              | 19 cal/g              | 1 hour           | 0.060 mL/g              |
| $\beta'$  | 27-29              | 28 cal/g              | 1 month          | 0.080 mL/g              |
| $\beta$   | 34-35              | 36 cal/g              | Stable           | 0.097 mL/g              |

development of stable crystals. Tempering involves the basic steps of

1. Complete melting
2. Cooling to initiate crystallization
3. Warming to melt out unstable crystals
4. Crystal development

Molten chocolate is typically stored at 45-50°C, a temperature range that is sufficiently high to preclude the development of any fat crystals. If previously crystallized chocolate is remelted, once melted it must be maintained within this temperature range for at least 30 min to 1 h to ensure all traces of cocoa butter crystals have been melted out prior to any further processing. The mass is then cooled, with agitation, to 28-29°C over a period of about 20 min. During this time, sensible heat is removed from the cocoa butter, the continuous phase, which in turn cools the cocoa and sugar and any other solids; thermal movement of the molecules slows. Eventually, the molecular motion slows enough to permit triglycerides to interact as they approach one another. Ultimately, they begin to pack together in a triple chain length chair configuration. As ordering progresses, the viscosity begins to build, thus impeding mobility of molecules, consequently prolonging the time required for a triglyceride to orient and mesh into a packing site.

Ideally, a proper balance must be imposed such that molecular motion is slowed enough to permit individual triglycerides to orient properly to establish lattices and yet not impede movement to the extent that reorientation into a more favorable conformation is precluded (36). Cooling can be accommodated with either about 18°C circulating air or a 25°C water jacket. Lower temperatures are to be avoided as they may result in localized shock cooling with the subsequent formation of unstable crystals. The chocolate is maintained at 28-29°C under agitation for several minutes to permit development of seed crystals. Only a very small proportion of the cocoa butter, 1-4%, needs to be crystallized at this stage if very small crystals are formed. As cocoa butter crystallizes, the total amount of solids present in the mass increases and consequently the viscosity increases.

The objective of tempering or precrystallization then is to introduce the proper quantity, size, and polymorph of seed crystals such that substantial

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may require a matter of hours to a matter of months. Cocoa butter exhibits complex polymorphism because of the small differences among the constituent symmetrical triglycerides. Because cocoa butter is a product of nature, its origin and climatic conditions within the growing region will alter its triglyceride profile to a degree. An additional variable is introduced by the process selected for extraction of butter from the bean. Consequently, a range of melting points have been reported over the years as each polymorph was identified. Today, six forms are generally recognized (Table 9.8) (32-34).

The crystal forms become progressively more stable moving from form I through form VI. The  $\gamma$  form (form I) crystallizes below 17°C and rapidly transforms spontaneously into  $\alpha$  (form II). This crystal remains viable about 1 h and melts around 23°C. All transitions between forms I and IV occur in the liquid state while the conversion from form V to VI is a solid-state transition.

Classification schemes are further complicated by the fact that forms III and IV have been proposed to be  $\beta'$  polymorphs and that forms V and VI are thought to be similar to one another and both  $\beta$ . Dr. S. V. Vaack studied cocoa butter extensively and much of his work was summarized in a Swiss publication, the *International Chocolate Review*, between 1951 and 1955 (35). The melting points he reported (Table 9.9) for the  $\alpha$ ,  $\beta'$ , and  $\beta$  polymorphs agree closely with those published by Johnston and Willie and Lutton (Table 9.8).

### 1.7 Tempering

Given the foregoing, it is clear that cocoa butter must be "encouraged" into the appropriate crystal form so that products formulated with this fat exhibit the physical properties desired. Attributes affected in chocolate include appearance (gloss and gloss retention), snap, contraction, texture, and overall product acceptability. The technique of tempering is applied to promote the

Table 9.8 Cocoa butter polymorphs and their melting ranges reported by various researchers (32-34)

| Form   | Systemic Nomenclature            | Melting Point (°C) |               |
|--------|----------------------------------|--------------------|---------------|
|        |                                  | Johnston           | Willie/Lutton |
| I      | $\gamma$ (sub $\alpha$ ) (gamma) | 16-18              | 17.3          |
| II     | $\alpha$ -2                      | 21-24              | 23.3          |
| III    | $\beta$ -2                       | 25.5-27.1          | 25.5          |
| IV     | $\beta$ -2                       | 27-29              | 27.5          |
| V      | $\beta$ -3                       | 30-33.8            | 33.8          |
| VI     | $\beta$ -3                       | 34-36.3            | 36.2          |
| VII(?) | —                                | 38-41              | —             |

and unmanageable increases in viscosity are avoided. Small seed crystals are also advantageous from a crystallization kinetics perspective. Attraction of a triglyceride to a growing crystal matrix is favored over the association and interaction of free triglycerides to form new nuclei. Therefore, a large number of smaller crystals is more conducive to progression of the crystallization process than is a much smaller quantity of substantially larger aggregates. Unstable  $\beta'$  (form IV) as well as the preferred  $\beta$  crystals will have formed over this crystallization range. Hence, the temperature is increased 2 or 3°C to promote transition to the stable  $\beta$  (V) form and melt out unstable  $\beta'$  crystals. It is critical that hereafter the temperature of the chocolate mass is never permitted to exceed 33°C, even that portion in direct contact with tank walls, because the stable crystals formed as a result of tempering will be melted out. The process required for milk chocolate is exactly the same except that all temperatures are reduced about 1°C (or more depending on the milk fat content) to accommodate the diluent effect of milk fat. Other approaches to introduce temper include (1) partial melting, (2) seeding, and (3) the mush method. The first two techniques require properly tempered solid chocolate.

The "partial melt" technique involves melting the solid chocolate, preferably broken into chunks first, and heating to 37–38°C. Thereafter, a solid chunk of chocolate representing about one fourth the weight of the molten chocolate is added and melted into the main mass with stirring. As the chunk melts, the temperature of the melted chocolate falls, and when it reaches 31–32°C, any remaining unmelted chocolate is removed. The molten chocolate is now in temper.

The "seeding" method, on the other hand, requires only a small portion of tempered solid chocolate shavings. The chocolate to be tempered is melted completely to 45–50°C and then cooled with stirring to 32–34°C. The tempered chocolate shavings, representing about 5% of the quantity of molten chocolate to be tempered, are stirred into the cooled main mass. As the shavings melt, the temperature of the chocolate falls to the desired range of 31–32°C and is tempered and ready to use.

The time-honored "mush" method was traditionally used by hand dippers. Chocolate is melted completely to 45–50°C and then cooled with stirring to 35°C. About one fourth of the chocolate to be tempered is poured onto a marble slab at room temperature. The puddle of melted chocolate is worked back and forth with a spatula on the slab as it cools. As crystallization progresses, the puddle thickens and becomes dull and mushy. This portion is then added back into the molten mass with stirring to produce tempered chocolate (37–39).

As was mentioned earlier, proper tempering will develop approximately 1–4% of the available cocoa butter into the  $\beta$  polymorph. Criteria such as appearance, viscosity, and temperature are reasonable indicators of how well tempered a chocolate mass is. However, considerable opportunity for error persists, and consequently a number of instruments have been developed over the years in an effort to quantify the degree of temper. Generally, these instruments evaluate the cooling curve (Figure 9.6) generated when a tem-

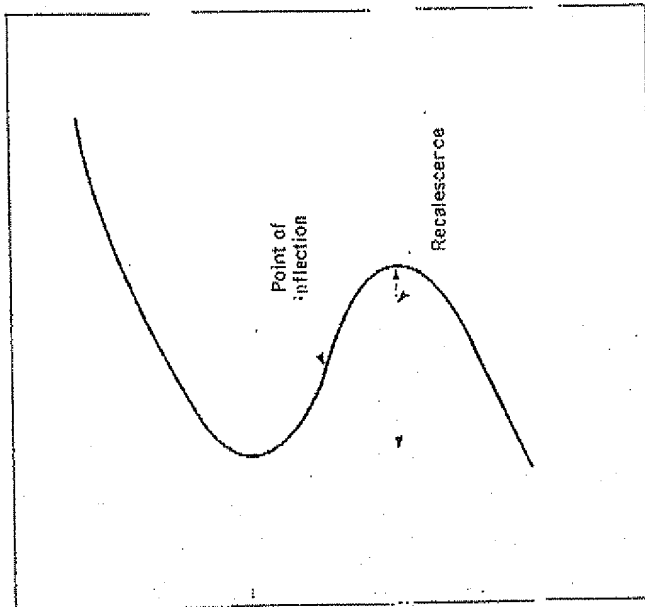


Figure 9.6 Typical cooling curve (tempering curve) for chocolate.

pered chocolate sample is cooled under prescribed conditions (a relationship exists between degree of temper and the cooling curve). Initially, the chocolate cools from the melt as sensible heat is removed and the temperature of the sample falls. Eventually, nucleation and crystallization occur and the resultant exotherm is evidenced by an increase in temperature. Ultimately, the capacity of the cooling medium to extract heat from the sample overcomes the exotherm and the temperature again falls.

Natural variability in the composition of cocoa butter can have a marked effect upon its temperability. Large amounts of  $\text{StOSt}$ , for example, enhance tempering because this triglyceride has a high crystallization rate in the  $\beta$  form. On the other hand, minor components (especially free fatty acids and monoglycerides) tend to retard crystallization. Wennermark (40) evaluated the influence of diglycerides and tristearin upon the crystallization rate of cocoa butter having the following composition:

|                   |      |
|-------------------|------|
| Free fatty acids, | 1.0% |
| 1,3-Diglycerides, | 1.1% |
| 1,2-Diglycerides  | 87%  |

Triglyceride composition (as % of total triglycerides):

StOSt, 25.5%  
 POSt, 40.5%  
 POP, 17.6%  
 Trisaturates, 1.6%  
 Others, 14.8%

To the reference cocoa butter, 5% of (1) 1,2-StSt, (2) 1,3-StSt, or (3) StStSt was added and the rate of  $\beta$  development evaluated by x-ray diffraction. The crystallization rate measured at 26°C was markedly retarded by 1,2-StSt and by StStSt but not affected at all by 1,3-StSt. Another crystallization experiment wherein only 1% of 1,2-StSt was added also significantly retarded the rate of  $\beta$  crystal development. Wennermark ascribes the differences between the impact of 1,2- and 1,3-diglycerides in this model system to their crystallization behaviors. Pure 1,2-diglycerides crystallize into an  $\alpha$  form and may transform into  $\beta'$  primer; 1,3-diglycerides immediately crystallize into the  $\beta$  polymorph, and consequently do not influence  $\beta$  development in cocoa butter. Given the foregoing, it is clear that even minor differences in the content of trisaturates and 1,2-diglycerides might be expected to impose a significant influence upon the temperability and crystallization properties of cocoa butter.

### 1.8 Cooling

Molten, tempered chocolate, whether applied to a center, molded into a solid form or hollow shell, deposited to form a chocolate chip, or applied as a stripe or swirl to a confection or baked good, must be further cooled to continue the crystallization process initiated during the tempering step. Properly tempered, properly cooled chocolate will transform into a brittle, glossy, stable, homogeneous form as the cocoa butter crystallizes. Ideally, chocolate is cooled and crystallized within a sanitary, dry environment that provides well circulated 18°C air. Very cold temperatures are to be avoided because they can (1) crystallize unstable, lower melting polymorphs, and (2) cause a skin of crystallized fat to form on the surface of pieces being cooled; the resultant insulation effect will greatly hamper heat removal from the interior and thus delay crystallization of deeper lying liquid cocoa butter. In either case, the end result will be unsatisfactory product and the eventual formation of fat bloom, a white haze of recrystallized surface fat that severely detracts from eye appeal and represents a quality defect. Bloomed chocolate products are certainly safe to consume; they just are not very attractive and to many consumers recrystallized fat has the appearance of mold. On the other hand, cooling chocolate at higher temperatures also compromises product quality. In this case, the crystallization process proceeds very slowly and consequently very large, grainy crystals develop. The finished chocolate will have a crumbly texture and mouthfeel, dull surface, and will eventually bloom.

Typically, insulated tunnels are employed for cooling, this final and very important stage of chocolate production. Air temperature, air velocity, and air direction relative to product travel and tunnel transit time are the parameters typically controlled in commercial cooling operations. The laws of nature apply to the heat exchange process that occurs and include conduction, convection, and radiation.

Two types of cooling tunnels prevail in the industry—convection and radiant. The concept of convection tunnels involves primarily guiding cooling air down the tunnel. Product is placed onto a belt that traverses the length of the tunnel at a constant rate. Cool air is often introduced into the middle of the tunnel and flows toward either end. Thus, air moves countercurrent to product in the first half of the tunnel and cocurrent to product in the back half. This scheme has the advantage of gradually ramping temperatures down and then up again as product traverses the tunnel length. The air in the first stage or section of the cooler should range between 16 and 20°C to ensure the formation of considerable quantities of stable crystals and preclude the formation of unstable crystals. As product nears the middle of the tunnel, the temperature gradually falls to 10–16°C. This is typically the point in the crystallization process where the most heat is released. In the initial cooling period, primarily sensible heat is removed; but as product continues further into the tunnel latent heat of crystallization must be removed, and this represents a substantially greater content of energy than does sensible heat. Air velocity is important and higher velocities are capable of moving away greater quantities of heat at a given air temperature. The last third of the tunnel transit offers a gradual increase in temperature to typically 15–18°C. This warming is necessary to keep surface temperatures above the dew point of the air in the packing room, thereby preventing condensation from forming upon the surface of cooled product when exiting the tunnel. Surface moisture dissolves sugar and forms a syrup. Later, as the water evaporates, sugar recrystallizes to form a gray, rough surface similar in appearance to fat bloom. Radiant cooling relies primarily upon black, water-cooled radiation absorbers installed above the product as it travels the entire length of the tunnel. In addition, 6–12°C cooling water is generally circulated through tubes located beneath the belt to provide bottom cooling. The air within the tunnel remains relatively still. Although properly tempered and properly cooled chocolate products will exit from the cooling tunnel with a dry, glossy appearance and be firm and dry to the touch, the crystallization process is not complete. Some 15–20% liquid cocoa butter remains and will crystallize over the next 2 or 3 days. Product is therefore stored in a cool (16–21°C) dry environment to complete crystallization (41–43).

### 1.9 Standards of Identity

Any product labeled chocolate in the United States must comply with the criteria described in Food and Drug Administration (FDA) Title 21 CFR Part

163. The FDA adopted the original standards of identity for chocolate in 1944, and they have changed only relatively little over the years. On December 2, 1985, FDA solicited comments concerning the desirability of and need for amending the U.S. standards of identity for chocolate products to achieve consistency with the Codex Standard for Chocolate (Codex Standard 87-1981) developed by the Codex Alimentarius Commission. The commission, sponsored jointly by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), conducts a program to develop worldwide food standards. Because the United States is a member of the Codex Alimentarius Commission, it is obliged to consider all Codex standards for acceptance. The Codex Standards for Chocolate (Codex Stan 87-1981) define 14 products (*Worldwide Standard*):

- 2.1.1 Chocolate with the addition of sugars (3.1.1)
- 2.1.2 Unsweetened Chocolate without the addition of sugars (3.1.20)
- 2.1.3 Couverture Chocolate with the addition of sugars (3.1.3), which is suitable for covering purposes
- 2.1.4 Sweet (Plain) Chocolate with the addition of sugars (3.1.4)
- 2.1.5 Milk Chocolate with the addition of sugars and milk solids (3.1.5)
- 2.1.6 Milk Couverture Chocolate with the addition of sugars and milk solids (3.1.6), which is suitable for covering purposes
- 2.1.7 Milk Chocolate with High Milk Content with the addition of sugars and milk solids (3.1.7)
- 2.1.8 Skimmed Milk Chocolate with the addition of sugars and skimmed milk solids (3.1.8)
- 2.1.9 Skimmed Milk Couverture Chocolate with the addition of sugars and skimmed milk solids (3.1.9), which is suitable for covering purposes
- 2.1.10 Cream Chocolate with the addition of sugars and cream and milk solids (3.1.10)
- 2.1.11 Chocolate Vermicelli with the addition of sugars (3.1.11), which is in the form of grains
- 2.1.12 Chocolate Flakes with the addition of sugars (3.1.12), which is in the form of flakes
- 2.1.13 Milk Chocolate Vermicelli with the addition of sugars and milk solids (3.1.13), which is in the form of grains
- 2.1.14 Milk Chocolate Flakes with the addition of sugars and milk solids (3.1.14), which is in the form of flakes

Table 9.10 (excerpted from the Codex standards) lists the ingredients required for each product.

U.S. standards in 21 CFR Part 163 also define 14 cocoa products, six of which have similar, but not identical, counterparts in the Codex standard. The six U.S. standards are:

Table 9.10 Composition (% calculated on the dry matter in the product) of the chocolate products defined in Codex Standard 87-1981

|        | Constituents                          |              |              |              | Total Fat | Total Solids | Total | Total |
|--------|---------------------------------------|--------------|--------------|--------------|-----------|--------------|-------|-------|
|        | Product                               | Cocoa Butter | Cocoa Solids | Other Solids |           |              |       |       |
| 3.1.1  | Chocolate                             | 18           | 14           | —            | —         | —            | —     | —     |
| 3.1.2  | Unsweetened chocolate                 | 50           | —            | —            | —         | —            | —     | —     |
| 3.1.3  | Couverture chocolate                  | 31           | 25           | —            | —         | —            | —     | —     |
| 3.1.4  | Sweet (plain) chocolate               | 45           | 12           | —            | —         | —            | —     | —     |
| 3.1.5  | Milk chocolate                        | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.6  | Milk Couverture Chocolate             | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.7  | Milk chocolate with high milk content | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.8  | Skimmed milk chocolate                | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.9  | Skimmed milk couverture chocolate     | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.10 | Cream chocolate                       | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.11 | Chocolate Vermicelli                  | 12           | 14           | —            | —         | —            | —     | —     |
| 3.1.12 | Chocolate Flakes                      | —            | —            | —            | —         | —            | —     | —     |
| 3.1.13 | Milk chocolate Vermicelli             | —            | 25           | —            | —         | —            | —     | —     |
| 3.1.14 | Milk chocolate Flakes                 | —            | 25           | —            | —         | —            | —     | —     |

Source: From Codex Standards for Chocolate (World Standard forms of CAC 85-87-1981).

\* In their natural proportions.

§163.111 Chocolate liquor (also chocolate, baking chocolate, bitter chocolate, cooking chocolate, chocolate coating, bitter chocolate coating) is the solid or semisolid food prepared by finely grinding cacao nibs. To such ground cacao nibs, cacao fat or a cocoa or both may be added in quantities needed to adjust the cocoa fat content of the finished chocolate liquor.

§163.123 Sweet chocolate (also sweet chocolate coating) is the solid or semisolid food the ingredients of which are intimately mixed and ground, prepared from chocolate liquor and one or more of the optional dairy ingredients or combinations of ingredients. One or more of the optional dairy ingredients may be used in such quantity that the finished sweet chocolate contains less than 12 percent by weight of milk constituent solids. The finished sweet chocolate contains not less than 15 percent by weight of chocolate liquor. Bittersweet chocolate (also semisweet chocolate, semisweet chocolate coating, and bittersweet chocolate coating) is sweet chocolate which contains not less than 35 percent by weight of chocolate liquor.

§163.130 Milk chocolate (also sweet milk chocolate, milk chocolate coating, sweet milk chocolate coating) is the solid or semisolid food the ingredients of which are intimately mixed and ground, prepared from chocolate liquor (with or without the addition of cacao fat) and one or more of the optional dairy ingredients. One of the optional dairy ingredients or combinations of ingredients. The finished milk chocolate contains not less than 3.66 percent by weight milk fat, not less than 12 percent by weight of milk solids, and not less than 30 percent by weight of chocolate liquor.

§163.135 Buttermilk chocolate (also buttermilk chocolate coating) conforms to the standards of identity prescribed for milk chocolate by §163.130, except that:

(a) The dairy ingredients used are limited to sweet cream buttermilk, dried sweet cream buttermilk, or any combination of two or all of these.

(b) The finished buttermilk chocolate contains less than 3.66 percent by weight of milk fat and, instead of milk solids, it contains not less than 12 percent by weight of sweet cream buttermilk solids.

§163.140 Skim milk chocolate (also sweet, skim milk chocolate, skim milk chocolate coat-

ing) conforms to the definition and standard of identity . . . prescribed for milk chocolate by §163.130, except that:

(a) The dairy ingredients used are limited to skim milk, concentrated skim milk, evaporated skim milk, sweetened condensed skim milk, nonfat dry milk, and any combination of two or more of these.

(b) The finished skim milk chocolate contains less than 3.66 percent by weight of milk fat and, instead of milk solids, it contains not less than 12 percent by weight of skim milk solids. §163.135 Mixed dairy product chocolate conforms to the definition and standard of identity . . . prescribed for milk chocolate by §163.130, except that:

(1) The dairy ingredients used in each such article is a mixture of two or more of the following four components:

(i) Any dairy ingredient or combination of such ingredients specified in §163.130 . . .

(ii) One or more of the five skim milk ingredients specified in §163.140.

(iii) One or more of the three sweet cream buttermilk ingredients specified in §163.135.

(iv) Malted milk.

(2) Each of the finished articles may contain less than 3.66 percent by weight of milk fat and, instead of milk solids, it contains not less than 12 percent by weight of milk constituent solids of the components used.

## COCOA BUTTER ALTERNATIVES

The fat phase of chocolate, cocoa butter, is largely responsible for its desirable properties, which include a brittle nongreasy texture at and below room temperature, excellent storage qualities, and characteristically rapid melting near body temperature. However, chocolate exhibits other properties that challenge certain applications:

1. Chocolate is sensitive to temperature fluctuations; therefore the environment of distribution systems must be carefully controlled to maintain finished product appearance and integrity.
2. Chocolate is characterized by a strong contraction and very brittle texture upon setting. Such properties are less than optimal if a soft, spongy matrix is to be coated; cracking and flaking off are a certainty.
3. The presence of other fats in a coated center elicits shelf life concerns. Compatibility of center fats with cocoa butter in the chocolate coating must not be overlooked.
4. Chocolate requires careful tempering to ensure good set, gloss, and gloss retention.
5. Cocoa butter and chocolate liquor command premium prices; cocoa butter alternatives typically provide the opportunity to reduce total formulation cost not only as a function of their discount vis-à-vis cocoa butter but also basis production streamlining (e.g., the conche step can often be eliminated or significantly shortened and many cocoa butter alternatives do not require tempering—such options represent the opportunity to save production time and energy).

Chocolate analogues, formulations within which either some or all of the cocoa butter is replaced with an alternative fat, have been developed to address these issues and hence, in certain applications, offer technical advantages over chocolate. Analogues produced today are far superior to the cheap replacements for chocolate, known in the trade as grease coatings, that were common in the 1930s. This improvement can be attributed primarily to technological advances in the field of fats and oils processing. The concept and utility of "tailor-made" fats gained acceptance in the 1950s as evidenced by the number of patents describing the manufacture of cocoa butter alternative fats with specific physical and chemical properties. The dramatic increase in cocoa butter prices in 1953–1954 likely fueled this enthusiasm as demand for confectionery coatings reached an all-time high for that period. The confectionery industry became acquainted with and took advantage of the uniformity and versatility represented by cocoa butter alternative fats. These factors, coupled with economic advantages, firmly established a market for cocoa butter alternatives (44). Cocoa butter alternatives, often referred to generically as hard butters, exhibit varying degrees of similarity to cocoa butter in terms of percent solid fat at room temperature, rapid complete melting at or near body temperature, and high stability. Major market segments for such fat systems include confectionery, biscuit and cracker, and industrial chocolate companies (confectors) that manufacture coatings and drops for user industries.

Three chocolate coating analogues, known generically in the industry as compound coatings, are described in 21 CFR Part 163:

§163.150 Sweet cocoa and vegetable fat (other than cacao fat) coating is subject to the requirements . . . prescribed for sweet chocolate by §163.123, except that:

(a) In its preparation cocoa is used, instead of chocolate liquor, in such quantity that the finished food contains not less than 6.8 percent by weight of the nonfat cacao portion of such cocoa . . .

(b) In its preparation is added one or any combination of two or more vegetable food oils, vegetable food fats, or vegetable food stearins, other than cacao fat, which oil, fat, stearin, or combination has a melting point higher than that of cacao fat. Any such oil or fat may be hydrogenated.

(c) The requirement of §163.123(a) that the milk constituent solids be less than 1.2 percent by weight does not apply.

§163.153 Sweet chocolate and vegetable fat (other than cacao fat) coating (a) conforms to the definition and standard of identity . . . prescribed for sweet chocolate by §163.123, except that:

(1) In its preparation there is added one or any combination of two or more vegetable food oils or vegetable food fats, other than cacao fat, which oil, fat, or combination may be hydrogenated and which has a melting point lower than that of cacao fat.

§163.155 Milk chocolate and vegetable fat (other than cacao fat) coating (also sweet milk chocolate and vegetable fat [other than cacao fat] coating) conforms to the definition and standard of identity . . . prescribed for milk chocolate by §163.130, except that:

(1) In its preparation there is added one or any combination of two or more vegetable food oils or vegetable food fats other than cacao fat, which oil, fat, or combination may be hydrogenated and which has melting point lower than that of cacao fat.

Cocoa butter alternatives are used to either replace or extend the cocoa butter component present in traditional chocolate. These fats find utility far beyond the coatings described in 21CFR. They are also widely used in molded products (solid as well as shell), centers, and for deposits like drops and inclusions. Hard butters are also used in the formulation of nonchocolate coatings, more commonly referred to as pastels, which are available in various colors and flavors. The very desirable properties of cocoa butter provide the quality standards against which alternative fats are evaluated. The fat phase, just as is the case for cocoa butter in chocolates, provides a continuous matrix that holds the other ingredients contributing to flavor, aroma, and color in an acceptable form prior to consumption. Relatively high levels of solid fat are required at room temperature, generally at or near 90%, to preclude a greasy or tacky feel on handling. Upon consumption, the fat must melt away rapidly and completely to maximize flavor release. The cocoa butter alternative selected will largely determine the flavor release and flavor stability, initial gloss and gloss retention, hardness and snap, compatibility with other fats present in the formulation, and rate of crystallization and contraction. The nonfat solids (primarily cocoa solids, sugar, and milk solids) will contribute significantly to the flavor, color, and palate perception of fineness. Together, these phases will establish the overall quality, rheological properties, price, and consequently acceptability of the finished goods.

One useful approach to the classification of cocoa butter alternatives is to consider the dominant properties of the source oils present. Three families emerge: cocoa butter equivalents and extenders (CBEs), nonlauric cocoa butter replacers (CBRs), and lauric cocoa butter substitutes (CBSs). Each family can be further resolved into a variety of subcategories of specialty fat classes. Cocoa butter equivalents and extenders are composed of the same types of triglycerides as cocoa butter and consequently must be tempered: CBRs and CBSs, on the other hand, are formulated with triglycerides quite different from those in cocoa butter, and they crystallize spontaneously (without tempering) into their stable  $\beta'$  polymorph upon cooling. Table 9.11 summarizes (the distinguishing characteristics for each category).

With deference to the regulatory constraints concerning the use of the term "chocolate," the following terminology will be employed to discuss formulations/applications that contain cocoa butter alternatives:

Chocolate—contains only cocoa butter and dairy fat.

CBE chocolate—some or all of the cocoa butter is replaced with a CBE.

CBR chocolate—most or all of the cocoa butter is replaced with a CBR.

CBS chocolate—all of the cocoa butter is replaced with a CBS.

## 2.1 Cocoa Butter Equivalents

The terms cocoa butter equivalent and cocoa butter extender are often used interchangeably; however, technically they describe separate product categories.

Table 9.11 Distinguishing characteristics of cocoa butter and cocoa butter alternatives

| Percent            | Cocoa Butter | CBE     | CBR      | CBS      |
|--------------------|--------------|---------|----------|----------|
| C8                 | —            | —       | —        | 3        |
| C10                | —            | —       | —        | 3        |
| C12                | —            | —       | —        | 54       |
| C14                | —            | —       | —        | 20       |
| C16                | 25           | 30      | 12       | 9        |
| C18                | 36           | 30      | 14       | 10       |
| C18:1              | 24           | 35      | 67       | —        |
| C18:2              | 3            | 3       | 6        | —        |
| Tempering required | Yes          | Yes     | No       | No       |
| Stable crystal     | $\beta$      | $\beta$ | $\beta'$ | $\beta'$ |

ries. Equivalents are fats that behave like and are compatible with cocoa butter in any proportion. They do not alter the melting, processing, and rheological properties of cocoa butter, and they have physicochemical characteristics similar to cocoa butter. Extenders, on the other hand, can be mixed with cocoa butter to a limited extent without significantly altering its melting, processing, and rheological properties. They do not necessarily have physicochemical characteristics similar to cocoa butter. The degree of compatibility, a function of triglyceride profile (Table 9.12), determines the quality of the extender. Equivalents may also be used as extenders. Source oils for the production of CBEs are all of tropical origin and include:

Palm (*Elaeis guineensis*) fat from Malaysia, Indonesia, West Africa, Papua New Guinea, and South America

Illipe (*Shorea stenoptera*) fat, sometimes referred to commercially as green butter, from the island of Borneo.

Shea (*Butyrospermum parkii*) fat from the savanna regions of West and Central Africa

Sal (*Shorea robusta gacra* L.) fat from India

Kokum (*Garcinia indica choisy*) fat from India

The triglyceride composition and melting properties of illipe fat are similar enough to cocoa butter to permit its inclusion, without any special processing techniques, at significant levels. Kokum fat is rich in StOst triglycerides, and therefore is also a valuable raw material, without fractionation, for the production of CBEs. Cocoa butter typically contains some 80% symmetrical 2-oleo disaturated triglycerides. The positioning of the fatty acids with respect to one another is paramount to the unique melting properties of cocoa butter. However, palm and shea fats, for example, although good sources of the



Table 9.12 Typical fatty acid compositions and triglyceride profiles for selected CBE feedstocks (30)

|                | Cocoa Butter | Palm | Illipe | Shea | Sal | Kokum |
|----------------|--------------|------|--------|------|-----|-------|
| Palmitic (P)   | 25           | 45   | 16     | 4    | 5   | 2     |
| Stearic (St)   | 36           | 5    | 46     | 43   | 44  | 57    |
| Oleic (O)      | 34           | 38   | 35     | 45   | 40  | 40    |
| Linoleic (L)   | 2            | 10   | —      | 7    | 2   | 1     |
| Arachidic (Ar) | 1            | —    | 2      | —    | 7   | —     |
| PPP            | —            | 5    | —      | —    | —   | —     |
| POSt           | 39           | 3    | 35     | 5    | 11  | 5     |
| StOSt          | 26           | —    | 45     | 40   | 42  | 72    |
| POP            | 16           | 26   | 7      | —    | 1   | —     |
| StOAr          | 2            | —    | 4      | 2    | 13  | —     |
| StLP           | 4            | 2    | —      | —    | —   | —     |
| PLP            | 2            | 7    | —      | —    | —   | —     |
| StLSi          | 1            | 2    | —      | —    | —   | —     |
| PPO            | —            | 5    | —      | —    | —   | —     |
| StOO           | 4            | 3    | 3      | 27   | 16  | 15    |
| POO            | 4            | 19   | —      | 2    | 3   | —     |
| StOL           | —            | —    | —      | 6    | 1   | —     |
| OOO            | —            | 3    | —      | 5    | 3   | 2     |

desirable SUS triglycerides, are significantly softer than cocoa butter. This is due to the high levels of di- and triunsaturated glycerides also present. In addition, palm fat contains significant levels of PPO, a triglyceride much less compatible in crystalline behavior with cocoa butter. Such undesirable triglycerides can be separated via fractionation processes including dry pressing, solvent, and detergent. Selective blending of whole fats and/or fractions yields hard fats suitable for CBEs.

Biotechnology provides another avenue for the production of CBEs. Genetic manipulation of oil-producing plants, harvesting lipids from single-cell organisms, and enhancing traditional process capabilities with the specificity offered by enzymes represent the biologically based technologies currently under development. High-oleic varieties of sunflower and safflower oils, for example, represent excellent sources of oleic feedstocks for the production of SUS triglycerides obtained by introduction of saturated fatty acids at the 1,3-position (45). Such transesterification reactions are facilitated by lipases. This group of enzymes catalyzes the hydrolysis of triglycerides; the reaction is reversible and thus lipases will also encourage the formation of acylglycerols from fatty acids and glycerol. Enzymic modification permits the production of pure and specific products under mild conditions thereby severely limiting the extent of side reactions. A regiospecific lipase, for example, 3A from fermentation of a selected strain of *Mucor miehei* fungus, will confine the

exchange of fatty acid groups to the  $\alpha$  positions on the triglyceride. The process can be made continuous by immobilization of the enzyme; this also provides the opportunity to reuse the lipase (46).

Macrae has described one such example that involves the directed interesterification of palm midfraction (rich in POP) with either stearic acid or tristearin to produce the following new triglycerides: POSt, StOSt, PSiP, and PSiSt. Fractionation typically follows to further tailor the triglyceride families to mirror the distribution characteristic of cocoa butter (47). Single-cell oils represent another potential source of oils and fats that might be suitable elements for CBE formulations. Yeasts and molds (both eukaryotic organisms) can accumulate substantial quantities of triglycerides, up to 70% of their dry cell weight; these lipids are generally similar in both fatty acid distribution and triglyceride profile to vegetable oils and fats (48). Bacteria, on the other hand, tend not to accumulate substantial quantities of lipids; or if they do, those products generally are other than triglycerides. Consequently, bacteria are of less commercial interest as a potential source of specialty lipids than are yeasts and fungi (49). The cost of the carbon source to sustain single-cell oil producers is a major impediment to widespread commercialization of the process, and therefore their niche is in value-added areas like CBEs (50). It is also possible to alter, *in vitro*, the composition of the lipids accumulated by single-cell organisms. Cells can be grown on a medium rich in stearic acid, for example, to encourage its uptake and incorporation directly into triglycerides as they are synthesized. This approach tends to circumvent the natural tendency to preferentially desaturate stearic acid over elongating palmitic acid (51).

The additional cocoa butter required for the formulation of a dark sweet chocolate could be replaced with a completely compatible CBE. No changes are necessary in the manufacturing process since the cocoa butter-CBE blend contains the same symmetrical triglycerides as cocoa butter and hence requires tempering. The term "supercoating" has often been used to describe a CBE chocolate so formulated. It is in fact even possible to completely replace the chocolate liquor with the appropriate proportions of CBE and cocoa solids (Table 9.13). From a formulation perspective, it is important not to overlook the fact that the final processing step applied during the production of CBEs (and any other cocoa butter alternative) is deodorization, and consequently a bland and odor-free CBE replaces aromatic cocoa butter. On the other hand, for recipes that contain deodorized cocoa butter, replacement of that butter with a CBE will not, of course, alter the flavor impact or intensity.

The symmetrical triglycerides POP, POSt, and StOSt are key to the performance of CBEs. Their  $\beta$  polymorphs melt at 38, 37, and 43°C, respectively; consequently the hardness of a given CBE is determined to a great extent by the quantity of each of these triglycerides present. The possibility to alter the relative proportions of POP, POSt, and StOSt in a CBE offers the opportunity to incorporate a harder cocoa butter alternative into a CBE chocolate that (1) contains a softer cocoa butter, (2) is severely softened by high amounts

Table 9.13 Typical recipes for chocolate, CBE chocolate, and supercoating<sup>a</sup>

|                         | Chocolate<br>(%) | CBE<br>Chocolate<br>(%) | Supercoatings (%)        |  |
|-------------------------|------------------|-------------------------|--------------------------|--|
|                         |                  |                         | Cocoa Butter<br>Replaced | Cocoa Butter<br>and Liquor<br>Replaced |
| Chocolate<br>liquor     | 42.0             | 42.0                    | 42.0                     | —                                      |
| Cocoa butter            | 8.4              | 2.0                     | —                        | —                                      |
| Cocoa powder<br>100(24) | —                | —                       | —                        | 20.8                                   |
| CBE                     | —                | 6.4                     | 8.4                      | 29.6                                   |
| Sugar                   | 49.6             | 49.6                    | 49.6                     | 49.6                                   |
| Fat content             | 31.9             | 31.9                    | 31.9                     | 31.9                                   |

<sup>a</sup> Lecithin added to each formula at 0.2–0.5% (salt and other flavors as required).

of milk fat (a function of the diluent effect of milk fat upon cocoa butter), or (3) that requires some tolerance to warmer temperatures. In general, SUS triglycerides are highest in Malaysian cocoa butters, somewhat less in African butters and lowest in South American cocoa butters. These natural variations can be largely dampened with the incorporation of an appropriate CBE into the recipe. Mixing, tempering, and crystallization of CBE chocolate is fundamentally as described for chocolate. Certainly, it is possible to include milk products in formulations if milk CBE chocolate is desired. Or, cocoa solids can be completely eliminated to produce a "white" CBE chocolate.

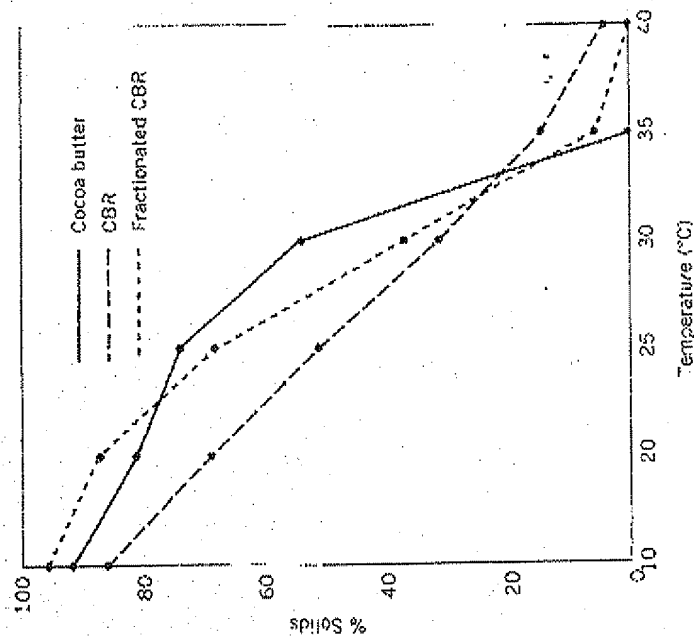
## 2.2 Cocoa Butter Replacers

Nonlauric cocoa butter replacers (CBRs) are derived from partially hydrogenated or partially hydrogenated and fractionated blends of primarily soybean, cottonseed, canola, and palm oils. These source oils are essentially composed of triglycerides containing 16 and 18 carbon atom fatty acids. In the United States CBRs are also often referred to as "domestic hard butters" because many of the currently available products are formulated with oils produced domestically. The triglycerides of the source oils typically utilized for the production of CBRs have relatively high levels of unsaturated fatty acids and thus are far too soft and unstable in their native forms. Soybean and cottonseed oils, for example, are liquid at room temperature and melt at around  $-17$  and  $-2^{\circ}\text{C}$ , respectively. Selective partial hydrogenation techniques including elevated temperatures, reduced hydrogen gas pressure, and partially inactivated nickel catalyst such as previously used catalyst or commercially available sulfur-promoted catalysts are required to manufacture these products.

The selective hydrogenation process favors the production of trans oleic acid and minimizes the formation of cis oleic acid (trans isomer of oleic acid).

occurring cis oleic acid to the trans form dramatically improves solid fat content at room temperature while minimizing the level of solid fat remaining at body temperature. The reaction can be terminated at melting ranges slightly higher than body temperature with a resultant acceptable level of solid fat at room temperature. Oxidative stability is improved as a result of reduction of the number of carbon-to-carbon double bonds and the superior resistance of trans isomers to oxidation. Partially hydrogenated CBRs fall short of the melting properties of cocoa butter because of the triglyceride families available for tailoring via isomerization and hydrogenation of their constituent fatty acids.

Compared to chocolate, CBR chocolates formulated with these alternative fats generally are characterized by poor eating quality, poor snap, and a low coefficient of contraction resulting in poor mold release. The limited compatibility of CBRs with cocoa butter generally precludes the inclusion of chocolate liquor in most formulations. Hence, low-fat cocoa powder is required and is the source of chocolate color, aroma, and flavor. The inherently poor flavor release characteristics of these fats obviously works against the percep-



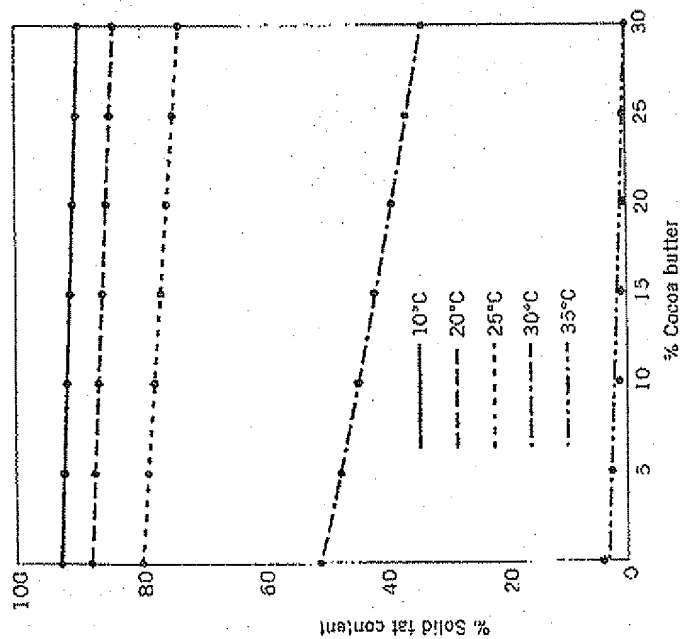


Figure 9.8 Influence upon solid fat content of incremental additions of cocoa butter into CBR solids diagram.

tion of flavor notes in CBR chocolates. However, these hard butters are associated with fair to good gloss and good shelf life. Cocoa butter replacer chocolate handling is relatively simple in that it is merely brought to a fully molten state and crystallized without tempering. This is possible due to minimal tendencies toward polymorphism in crystal structure. These fats crystallize in the  $\beta'$  form, which practically speaking, is the desired stable polymorph (ultimately, CBR fats will recrystallize to  $\beta$ ). Thus, CBR chocolate products tend to maintain acceptable gloss following heat stressing and subsequent recovery to ambient temperature. Market applications include biscuit and cracker coatings, economy baking chips, and high-bulk/low-cost candy bar coatings.

The physical and functional properties of CBRs can be improved by controlled crystallization and separation techniques. Some fractionation processes involve the use of food-grade solvents while others accomplish separation simply by cold, dry pressing. Figure 9.7 illustrates that the resultant selective

concentration of desirable triglycerides significantly improves solid fat content at room temperature and narrows the melting range while effecting only a marginal change in the melting point.

Some of these products reportedly tolerate up to 25% cocoa butter in the total fat phase of a CBR chocolate. Admixture with cocoa butter up to this limit slightly softens CBRs and thus has the important effect of improving eating quality by reducing the amount of solid fat present at mouth temperature (Figure 9.8). Maximum improvement of mouth melt occurs at about a 10% addition of cocoa butter (fat basis).

The limited compatibility with cocoa butter is a function of the similarity in chain length shared between fatty acids associated with cocoa butter and CBR triglycerides (Table 9.14).

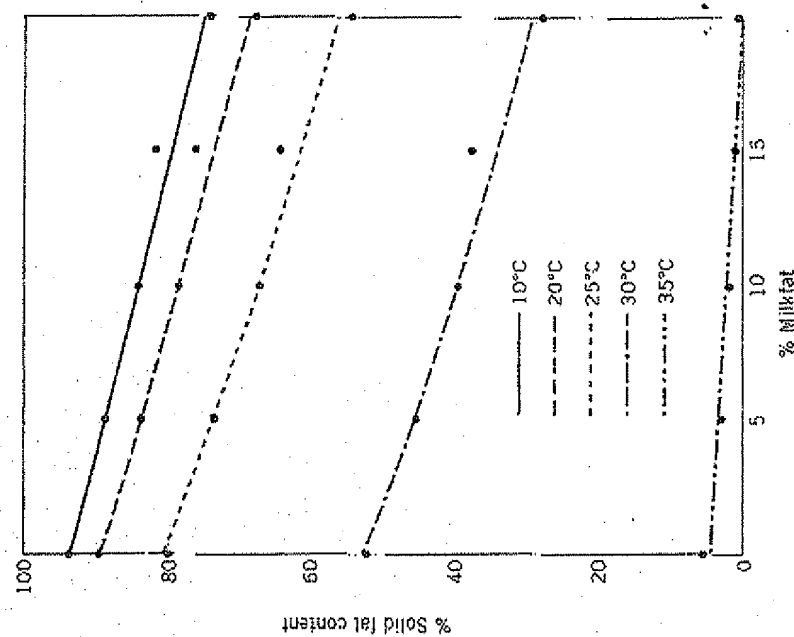


Figure 9.9 Influence upon solid fat content of incremental additions of milkfat—solids diagram.

Table 9.14 Typical composition of soy-based CBR<sup>a</sup>

| Fatty Acid Composition |           | Triglyceride Profile |     |
|------------------------|-----------|----------------------|-----|
| C16 (P)                | 12% (25%) | OEIEI                | 10% |
| C18 (S)                | 13% (36%) | POEI                 | 6%  |
| C18:1 (O)              | 69% (34%) | EEIEI                | 25% |
| C18:2 (L)              | 5% (2%)   | PPO                  | 2%  |
|                        |           | SEIEI                | 10% |

<sup>a</sup> Cocoa butter fatty acid composition is given in parenthesis for reference.

Cocoa butter admixture prolongs the setting time (see Table 9.16) and reduces the gloss and gloss shelf life of CBR chocolate. Milk fat is often a component in CBR chocolate and it interacts with the CBR fat as well. Like cocoa butter, it softens the CBR, but in a predictable linear manner and thus also can be used to advantage for improvement of mouthmelt. Again, like cocoa butter, milk fat delays setting time but it conveys the benefit of improved gloss stability. The severe softening resulting from the addition of milk fat limits its inclusion to between 10 and 15% of the fat phase (Figure 9.9).

Cocoa butter replacer chocolates (Table 9.15) generally are described as having good mouthfeel and flavor release properties, good gloss and shelf stability, and are nontempering. Applications include enrobing better quality bakery products and high bulk candy bars as well as in the formulation of cookie drops. Cocoa butter replacers are especially attractive center fats in complex products that may contain moisture in the center (to preclude the risk of hydrolytic rancidity) or are coated with chocolate or CBE or CBR chocolate. Because they are less brittle and do not contract as severely as chocolate, CBRs are especially well suited to coatings for covering jellies, marshmallows, cakes, and other pliable or spongy substrates.

Cocoa butter replacer chocolate represents several advantages over chocolate and CBE chocolate:

1. Conching is generally eliminated or at least the time substantially minimized to a few hours.

Table 9.15 Typical CBR chocolate formulas<sup>a</sup>

| Ingredient                  | Milk (%) | White (%) | Dark (%) |
|-----------------------------|----------|-----------|----------|
| Chocolate liquor            | 9.0      | —         | 8.0      |
| Cocoa butter                | —        | 5.5       | —        |
| Cocoa powder (10–12%)       | 12.0     | —         | 16.0     |
| Whole milk powder (24% fat) | 13.0     | 30.5      | —        |
| Skim milk powder (<1% fat)  | 26.0     | 28.0      | 30.0     |
| Sugar                       | 40.0     | 36.0      | 46.0     |

<sup>a</sup> Lecithin added to each formula at 0.2–0.5% (salt and other flavors as

2. Tempering is generally not required; the stable  $\beta'$  polymorph forms spontaneously.

3. Provides a flexible, more elastic coating for soft or spongy substrates and hence precludes cracking and flaking off.

4. Tolerance to higher temperatures.

5. Lower cost.

## 2.3 Cocoa Butter Substitutes

Lauric cocoa butter substitutes (CBSS) represent a wide range of alternative fat systems. These products are predominantly lauric fats obtained from the oil palm and coconut palm. World supply is mainly of palm kernel and coconut origin. These differ from the nonlauric fats and oils in that their fatty acid compositions are 40–50% lauric acid. Hydrogenation to near saturation results in fats that melt relatively rapidly and cleanly upon heating as opposed to the gradual softening behavior of partially hydrogenated nonlauric fats. Furthermore, the inherently low levels of unsaturates, such as oleic and linoleic fatty acids, impart a high degree of oxidative stability to these fats. Such characteristics make the lauric fats particularly attractive to the confectionery industry. Processing techniques such as hydrogenation, interesterification, and fractionation are applied to provide a wide range of melting points and melting curves suitable for confectioners' applications. Interesterification is often combined with hydrogenation to manufacture "rearranged" or "modified" lauric hard butters. The interesterification process permits the random re-arrangement of the fatty acids on the triglyceride molecules with the aid of a catalyst such as sodium methoxide. The interesterification process does not change the degree of unsaturation or isomerization. This technique permits an increase in solid fat content at room temperature to required levels at melting points consistent with good melting properties (Figure 9.10). By employing a variety of oil blends, a wide range of solid fat contents and melting ranges are possible. Generally, these products are made from palm kernel and/or coconut fats in combination with lesser quantities of nonlauric fats such as palm, cottonseed, or soybean.

Formulation flexibility provides the ability to produce compound coatings suitable for almost any climate or season. It is not uncommon for a bakery item to be enrobed with a compound coating containing an interesterified CBS with a melting point of 37 or 38°C during winter months and 45°C or higher during summer months. Cocoa butter substitute chocolate formulated with an interesterified CBS typically exhibits good mouthfeel and flavor release, good gloss, good mold and belt release, and is hard and dry to the touch at ambient temperature. It also displays excellent oxidative stability. Coatings may be run either tempered or nontempered; however, tempering (or some form of conditioning) is generally advisable to maximize gloss and gloss retention. They crystallize quickly and therefore often represent a manufacturing

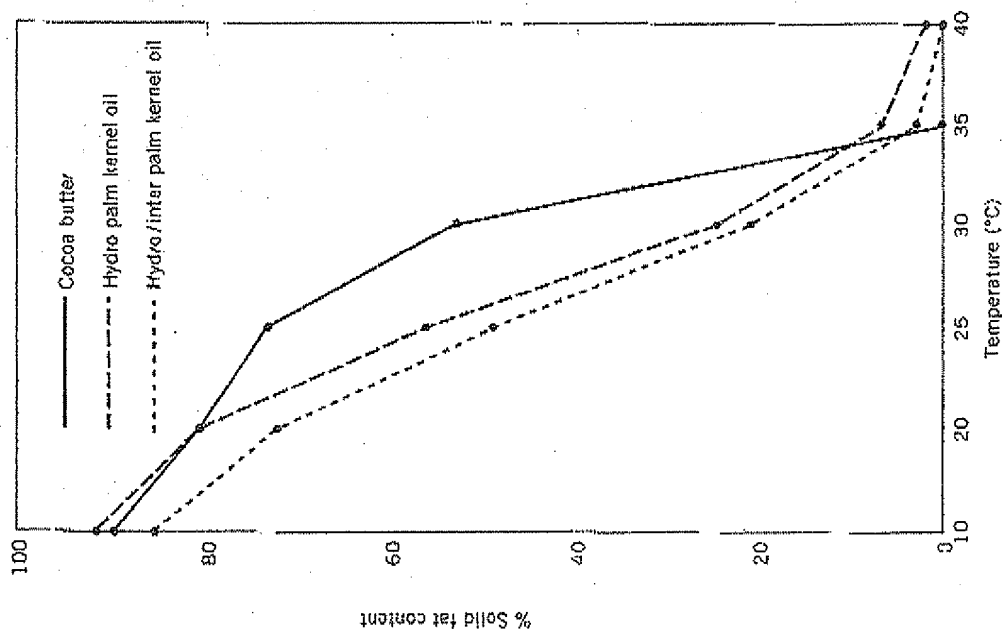


Figure 9.10 NMR curves for cocoa butter, hydro palm kernel oil, and hydrointeresterified palm kernel oil.

Table 9.16 Relative crystallization times for CBR and CBS chocolates as influenced by crystallization temperature and by cocoa butter content (of CBR)<sup>a</sup>

|                                  | Crystallization Temperature |      |        |
|----------------------------------|-----------------------------|------|--------|
|                                  | 5°C                         | 10°C | 12.5°C |
| CBS                              | 1.0                         | 1.2  | 1.5    |
| CBR (6% cocoa butter in recipe)  | 1.2                         | 1.3  | 1.7    |
| CBR (17% cocoa butter in recipe) | 1.5                         | 1.6  | 2.2    |
| CBR (25% cocoa butter in recipe) | 2.7                         | 2.9  | 3.9    |

<sup>a</sup> CBS crystallized at 5°C is assigned a value of unity.

Applications include coatings for bakery products and confectionery products in which the coating is important but is not the dominant factor in the eating quality of the product. The predominantly short-chain fatty acid composition of lauric fat triglycerides is largely responsible for their very limited tolerance to cocoa butter. Admixture of these fats with cocoa butter in excess of only a few percent results in a severe eutectic (Figure 9.11) with subsequent softening and dulling of a coating so formulated. Therefore, chocolate liquor is replaced with low-fat cocoa powder in most lauric based coatings (Table 9.17).

The highest quality CBS alternatives are those derived from fractionated palm kernel oil. Palm kernel steatins closely parallel the melting profile of cocoa butter. They offer the firmness, snap, and steep melting profile typical of cocoa butter but at a lower price. The manufacturing process involves crystallizing whole palm kernel fat under very specific conditions. The softer

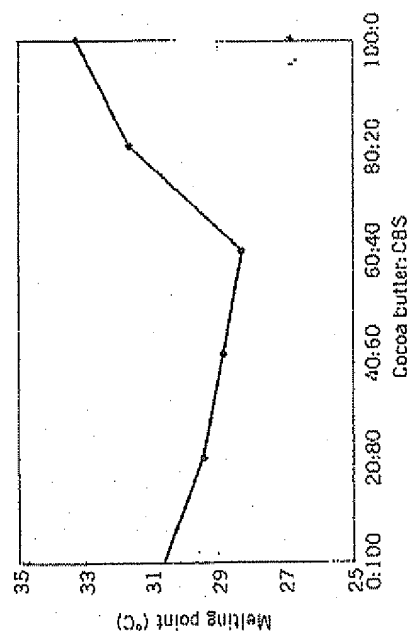


Figure 9.11 Admixture of cocoa butter with CBS-melting point eutectic.